Biological Evaluation of Fall Webworm on the Allegheny National Forest

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Abstract

During the late summer of 2011, the Allegheny National Forest (ANF) experienced an outbreak of a native defoliator, the fall webworm (*Hyphantria cunea* Drury (Lepidoptera: Arctiidae)), mainly on black cherry (*Prunus serotina*) trees. Moderate resolution imaging spectroradiometer (MODIS) data from the U.S. Forest Service Forest Health Technology Enterprise Team (FHTET) and Eastern Forest Environmental Threat Assessment Center (EFETAC) detected 16,268 acres of light, 4,872 of moderate, and 1,022 acres of severe change in the normalized difference vegetation index (NDVI) during this time. Field surveys and MODIS data for individual pixels were used to create an error matrix to assess the accuracy of the MODIS data. Field surveys of 33 pixels detected fall webworm activity at 79 percent of the sites visited. The overall accuracy (agreement) was 42.4 percent for FHTET data and 45.5 percent for EFETAC data when comparing the MODIS data (detectable/undetectable change) with the field assessments of defoliation (defoliated/undefoliated). The overall accuracy (agreement) for field data and MODIS change data when categorizing by level of change dropped to 30.3 percent for the FHTET data and 36.4 percent for the EFETAC data. Because the fall webworm is a late season defoliator and its outbreaks typically last 1 to 2 years, it is normally not considered a forest pest or an agent of high tree mortality, although those trees that experience high defoliation will likely have reduced growth and branch dieback. Fall webworm control measures are not currently needed in general forest areas of the Allegheny National Forest. However, we recommend that the Forest incorporate annual insect and disease monitoring into management plans for high-value areas such as campgrounds and, if needed, apply both long- and short-term insect and disease treatment strategies to minimize impacts and meet resource objectives.

Purpose and Need

The Morgantown Field Office (MFO) received a request from the Marienville Ranger District, located in the Allegheny National Forest, to evaluate the impact of fall webworm activity. The request came from District Ranger Rob Fallon, who recently observed fall webworm activity across the ANF. The MFO undertook this project to not only address this request but to identify any significant problems that might occur as a result of fall webworm defoliation on the ANF.

Project Location/Description

The Allegheny National Forest is located in northwestern Pennsylvania in parts of Elk, Forest, Jefferson, McKean, and Warren counties (41º45'N, -79º00'W). The ANF covers approximately 517,000 acres of which 463,000 acres are forested. The ANF lies within the hemlock-white pine-northern hardwood region (Braun, 1950). The hemlock-northern hardwood forest type of pre-settlement times was composed mainly of eastern hemlock (*Tsuga canadensis*) and American beech (*Fagus grandifolia*), and it has been replaced by the current mixed upland hardwoods and cherry-maple (Allegheny hardwood) types (Morin et al., 2006; Whitney, 1990). Currently, black cherry (*Prunus serotina*) and red maple (*Acer rubrum*) are the most abundant species in the ANF (Morin et al., 2006).

Project Objectives

The objectives for this evaluation were to 1) assess the current location and extent of fall webworm defoliation, 2) determine the likelihood of an outbreak in 2012, and 3) determine the need for management activities on the Allegheny National Forest.

Project Methods

MODIS Satellite Data

We used moderate resolution imaging spectroradiometer (MODIS) data to assess fall webworm activity in the ANF. We acquired MODIS and normalized difference vegetation index (NDVI) data with a resolution of 240 by 240 m² (~14-acre pixel) and 16-day interval composite data beginning on September 29, 2011, from the U.S. Forest Service Forest Health Technology Enterprise Team (FHTET), Remote Sensing Application Center (RSAC) and Eastern Forest Environmental Threat Assessment Center (EFETAC) work groups (figure 1). The data collected from both of these early warning systems uses the NDVI to measure and contrast the visible and near infrared spectral bands (Spruce et al., 2011). The NDVI relies on sensors aboard satellites to measure the absorption of red radiation by leaf pigments and chlorophyll and the scattering of the near infrared band by foliage to detect change (Beck et al., 2006). We compared the NDVI values of each pixel to a 3-year historical baseline value and determined the percent change. We

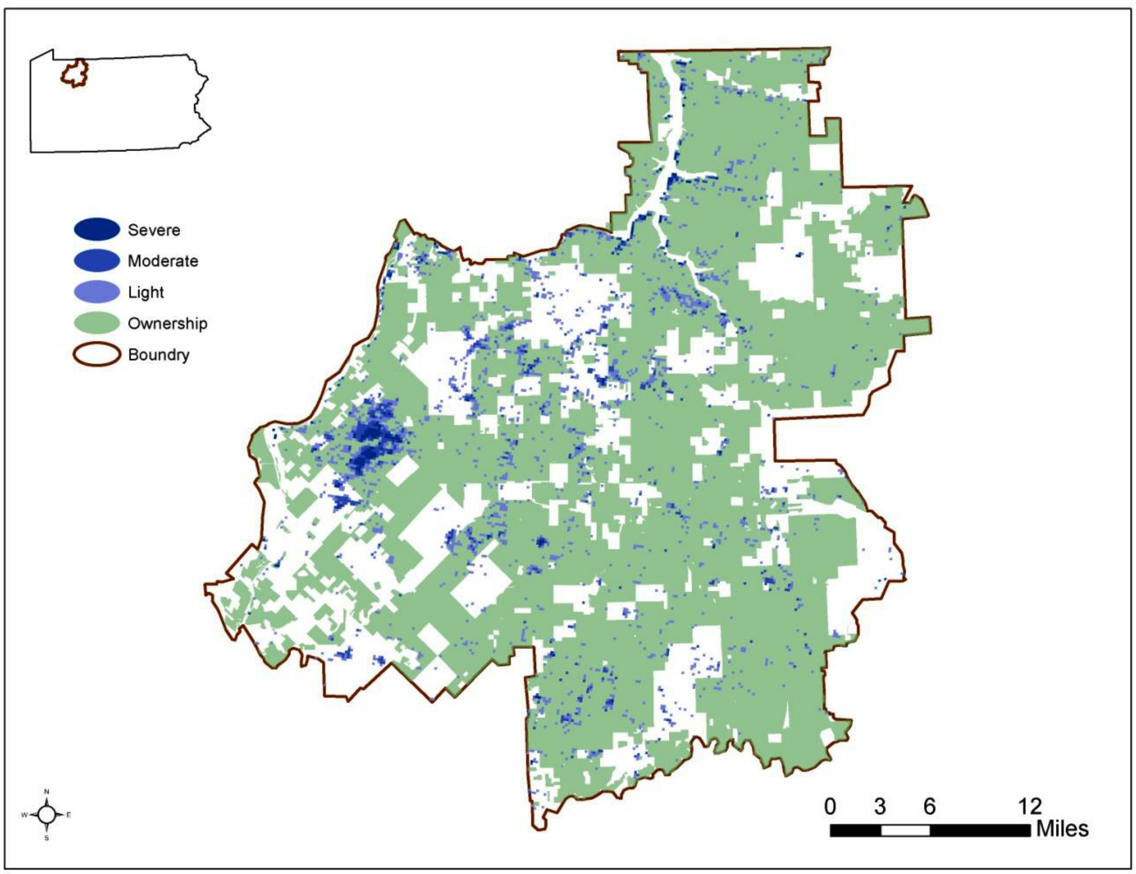

Figure 1. Forest disturbance on the Allegheny National Forest, Forest Disturbance Mapper change assessment for September 29, 2011.

then separated the NDVI values into four classes based on percent change from baseline: none (0 percent), light (1-9.9 percent), moderate (10-19.9 percent), and severe (>20 percent). We imported the MODIS data into the ARCMAP 10 (ESRI, Redlands, California) geographic information system (figure 1). We then manually grouped clusters of pixels showing detectable change into discrete areas of interest across the ANF.

We transformed the class data into binary data (detectable change/undetectable change) and used ARCMAP to create 1 mile buffers around the roads in each cluster. We used ARCMAP to randomly select 20 pixels from each of the binary data classes within the buffered are and then created field maps that included the UTM coordinates of each pixel.

Field crews were not told if detectable change was detected in the pixel or not. Field crews then used the GPS coordinates to survey the entire 14-acre pixel on October 10 and 11, 2011. At each pixel crews were asked to 1) note the presence/absence of fall webworm based on the presence of webworm nests, 2) determine the percentage of defoliation observed throughout the pixel (none, light (1-25 percent), moderate (26-50 percent), severe (>50 percent)), and 3) identify the species of trees being defoliated within the pixel. Field crews visited 33 of the 40 pixels selected.

MODIS Error Matrix

We used a cross-tabulated error matrix (Johnson and Ross, 2008) containing rows, columns, and diagonals to calculate two statistics comparing the field data and MODIS-based data: overall MODIS data accuracy and MODIS data accuracy for each change category. We calculated the overall accuracy for the MODIS data by dividing the total number of correct classifications, obtained by summing the diagonal cell values in the error matrix, by the total number of field sites visited. We calculated the MODIS data accuracy for each change category by dividing the cell in the diagonal by its corresponding column total (Johnson and Ross, 2008).

Aerial Detection Survey

Aerial sketchmapping surveys were conducted over the ANF on July 9, 2011, by personnel from the Pennsylvania Department of Conservation and Natural Resources Bureau of Forestry (figure 2). Until very recently, aerial sketchmapping has been the primary and most widely used remote sensing tool to assess forest health conditions. Trained observers working from low-flying aircraft locate areas of mortality or defoliation and “sketch” those locations on a digital sketchmapping system as coded points or polygons based on a predetermined classification system (de Oliveira et al., 2006).

Historic Review

The U.S. Department of Agriculture Forest Service has been preparing annual reports of nationally significant insect and disease conditions in the Nation’s forests since 1955. Locally important insect and disease conditions are reported at the region and State level. For this project, we reviewed Forest Insect and Disease conditions reports from 1955 to 2010 for information about the location and severity of fall webworm activity.

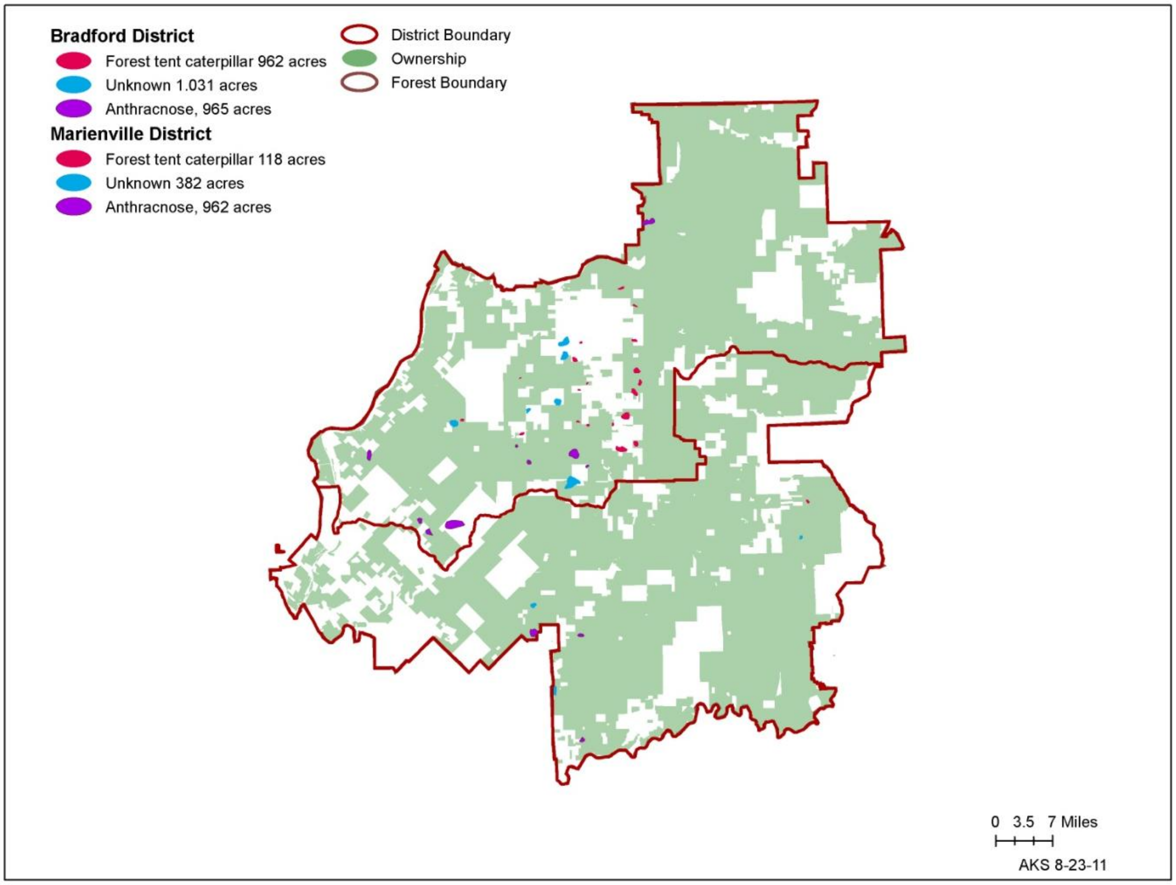

Figure 2. Results of an aerial survey of the Allegheny National Forest flown July 9, 2011.

Results

MODIS satellite data

MODIS satellite data collected from late September 2011 detected 16,268 acres of light change, 4,872 acres of moderate change, and 1,022 acres of severe change (figure 1). Field crews detected fall webworm activity at 79 percent of the sites visited. The error matrices in tables 1 through 4 present data for assessing the agreement and disagreement between the MODIS-derived data and field survey data. The shaded diagonal values show the agreement between the MODIS data and the field surveys; the other cells represent the disagreement (false negatives/false positives) between the MODIS data and field surveys (Johnson and Ross, 2008). When comparing the MODIS data (detectable/ undetectable change) with the visual assessments of defoliation (defoliated/undefoliated), the overall accuracy was 42.4 percent for the FHTET data and 45.5 percent for the EFETAC data. The levels of accuracy (agreement) for the field surveys and the FHTET and EFETAC data comparing undetectable change and undefoliated was 15.8 percent and 16.7 percent, respectively. The levels of accuracy (agreement) for the data comparing detectable change and defoliated was 78.6 percent and 80.0 percent, respectively (tables 1 and 2).

Table 1. Cross-tabulated error matrix of Forest Health Technology Enterprise Team (FHTET) MODIS data (undetectable/detectable change) with ground survey defoliation data (undefoliated/defoliated) for fall webworm, September 29, 2011.

	FHTET MODIS data		
Ground Survey	Undetectable change	Detectable change	Totals
Undefoliated	3	3	6
Defoliated	16	11	27
Totals	19	14	33
FHTET accuracy (%)	15.8	78.6	
Overall accuracy (%)	42.4		

Table 2. Cross-tabulated error matrix of Eastern Forest Environmental Threat Assessment Center (EFETAC) MODIS data (undetectable/detectable change) with ground survey defoliation data (undefoliated/defoliated) for fall webworm, September 29, 2011.

	EFETAC MODIS data		
Ground Survey	Undetectable change	Detectable change	Totals
Undefoliated	3	3	6
Defoliated	15	12	27
Totals	18	15	33
EFETAC accuracy (%)	16.7	80.0	
Overall accuracy (%)	45.5		

When comparing the MODIS data (level of change) with the field assessment by defoliation level, the overall accuracy dropped to 30.3 percent for the FHTET data and 36.4 percent for the EFETAC data. The levels of accuracy (agreement) for the field surveys ranged from 40 percent to 100 percent (tables 3 and 4). The highest level of agreement between the FHTET and EFETAC data and the field surveys occurred when comparing severe defoliation with severe change (tables 3 and 4). Field crews noted that the majority of the trees experiencing defoliation were black cherry. Other species reported as being defoliated were ash, beech, and red maple. Overstory trees were the most defoliated with less defoliation occurring in the mid and understory trees. Fall webworm activity within the individual pixels was highly variable and "patchy" depending on the age and composition of the stand.

Table 3. Cross-tabulated error matrix of Forest Health Technology Enterprise Team (FHTET) MODIS change data level with ground survey defoliation data level for fall webworm, September 29, 2011.

	FHTET MODIS data				
Ground Survey	None	Light	Moderate	Severe	Totals
None	3	2	1		6
Light	8	3	1		12
Moderate	4	2	2		8
Severe	4		1	2	7
Totals	19	7	5	2	33
FHTET accuracy (%)	15.8	42.9	40.0	100.0	
Overall accuracy (%)	30.3				

Table 4. Cross-tabulated error matrix of the Eastern Forest Environmental Threat Assessment Center (EFETAC) MODIS change data level with ground survey defoliation data level for fall webworm, September 29, 2011.

	EFETAC MODIS data				
Ground survey	None	Light	Moderate	Severe	Totals
None	3	2		1	6
Light	7	5			12
Moderate	3	3	2		8
Severe	5			2	7
Totals	18	10	2	3	33
EFETAC accuracy (%)	16.7	50.0	100.0	66.7	
Overall accuracy (%)	36.4				

Aerial Detection Survey

The aerial survey for 2011 detected 2,376 acres of defoliation caused by the fall webworm in the ANF (Turcotte 2011; figure 2). Although the flight did detect fall webworm activity, it likely occurred too early in the season to detect the full extent of fall webworm activity. As a result, this data was not used to evaluate fall webworm populations.

Historical Review

Records of fall webworm outbreaks in the Northeastern and Mid-Atlantic regions have been well maintained since 1955. Figure 3 displays the occurrence of outbreaks in the Northeastern and Mid-Atlantic regions over the past half century, which typically cycle every 7 or 8 years. Historical records from Canada revealed that in the northern part of its range the outbreak pattern averaged about 12 years (Morris, 1964). Outbreaks typically last about a year, although some may last 2 or 3three years. For the Northeastern and Mid-Atlantic regions, 64% of the reported outbreaks lasted 1 year; 22% lasted 2 years, and only 15% lasted 3 years or more (Figure 4). Fall

webworm outbreaks typically cycle every 7 or 8 years in the northeast (Figure 3).

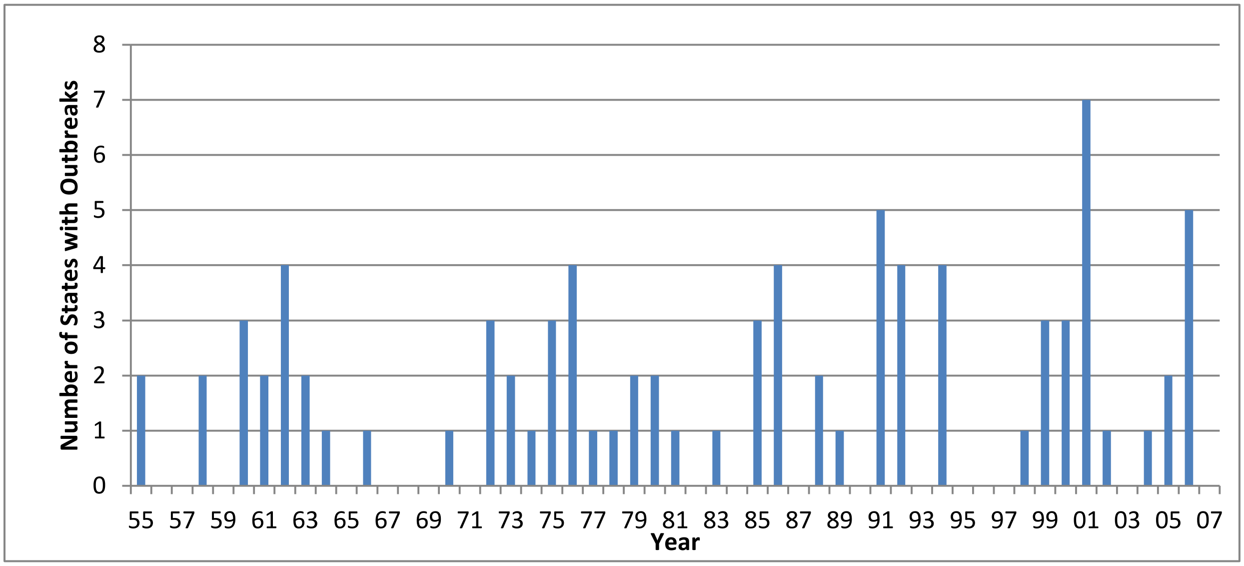

Figure 3: Number of states with fall webworm outbreaks in the Northeastern and Mid-Atlantic Regions by year (Data source: Forest Pest Condition reports 1955-2007).

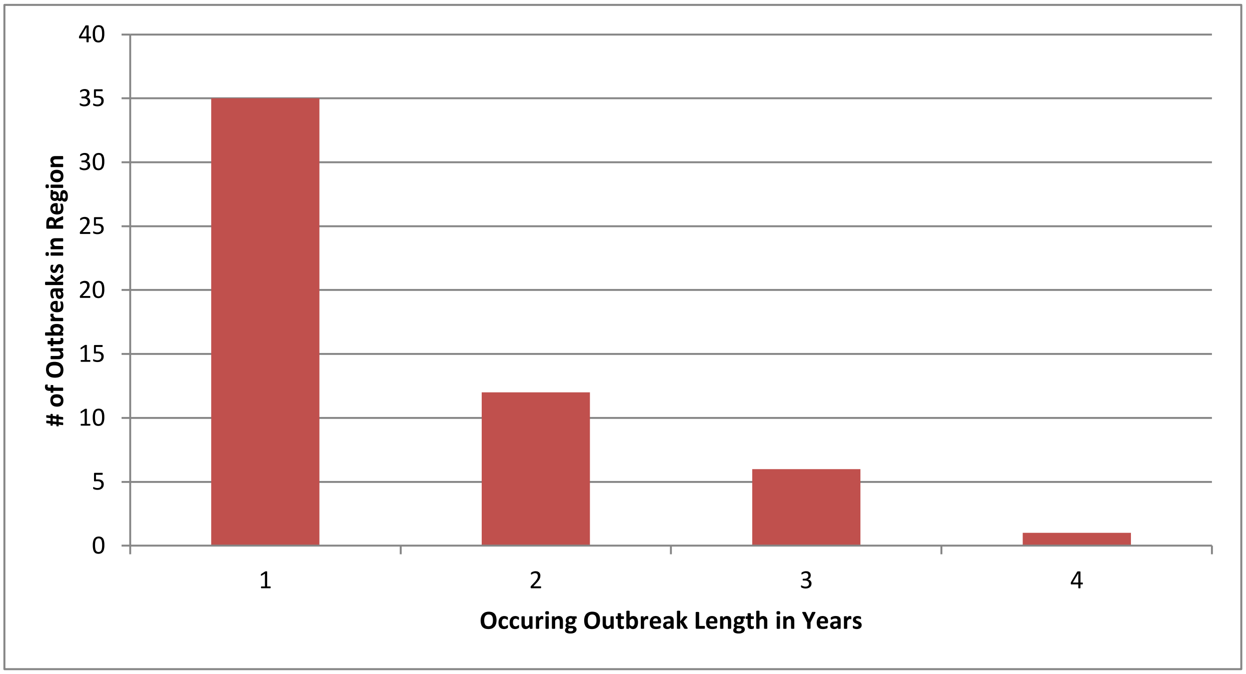

Figure 4. Duration of fall webworm outbreaks in the Northeastern and Mid-Atlantic Regions (Data source: Forest Pest Condition reports 1955-2007).

Species Evaluation

Introduction

The fall webworm, *Hyphantria cunea* Drury (Lepidoptera: Arctiidae), or the American white moth, is native to North America. It is present throughout the United States, southern Canada (Drooz, 1985) and has been introduced to Europe and Asia (Yearian et al., 1966). The larvae are colonial nest makers (Morris, 1964) that feed on more than 100 species of deciduous trees and shrubs (Drooz, 1985). Normally the fall webworm is not considered a major forest pest (Liebhold et al., 2012); however during periods of outbreaks, trees and shrubs can be completely defoliated causing branch dieback and top-kill (Drooz, 1985) as well as losses in growth and seed production (Oliver, 1964).

Biology

The adult stage of the fall webworm is brief lasting from 3 to 14 days, with the bright white (Figure 5), or white with dark spotted adult moths emerging in May-July depending on geographic location (Drooz, 1985; Morris and Fulton, 1970). Females generally mate and begin laying eggs within 1 to 3 days after emergence (Morris and Fulton, 1970). Female moths lay between 400 to 1000 light green or yellow eggs in a mass on the underside leaves in a single layer or a double layer, which is then covered with scales from the female abdomen (Sourakov and Paris, 2011). In 7 to 10 days, the larvae hatch and create a silken web before they start to feed on the foliage (Drooz, 1985). The webworms continue to eat inside the constructed nest, skeletonizing leaves (Figure 7) and continually extending the web to encompass fresh foliage on the tree branches (Morris 1967). As the larvae approach maturity some leave the web and feed individually (Drooz, 1985; Morris and Fulton, 1970). After they are finished feeding, they move into bark crevices or into the ground debris to spin their cocoons (Drooz, 1985; Sourakov and Paris, 2011). Larval development lasts 4 to 6 weeks, with the number of instars varying from 5 to 8 (Yearian et al., 1966). Mature larvae are hairy with either a lime green or darker body color

Figure 5. Fall webworm moth (left) and pupa (right). (Gerald J. Lenhard, Louisiana State Univ., Bugwood.org)

Figure 6. Fall webworm defoliates trees and skeletonizes the leaves for their source of food

(Sourakov and Paris, 2011) (Figure 5) and are about 2.5 cm long. Two phenotypes of larvae are known to exist based on the color of the head capsules (red headed and dark-headed larvae) (Sourakov and Paris, 2011). The overwintering pupa is pale greenish, darkening to a deep reddish-brown color and is approximately 8 to 14 mm long and 3.5 to 4 mm wide (Warren 1971, Figure 5). In the north where temperatures are colder, the webworm usually has just one generation per year, but the webworms in the southern states can have up to 4 different generations per year (McCullough and Siegert, 1999).

Figure 7. Fall webworm larvae. (Milan Zubrik, Forest Research Institute - Slovakia, Bugwood.org)

Host

The fall webworm feeds and defoliates over 100 different tree species (Drooz, 1985) and can be seen during the spring, summer, but mostly during the fall months creating their webs. The fall webworm is a generalist and is capable of feeding and developing on a large number of different deciduous tree species such as cottonwood, alder, black walnut, elm, birch, hickory, apple, pear, cherry, sycamore, maples, willow, oak, and poplar (Sourakov and Paris, 2011). The fall webworm is not just a forest pest; it can be found in ornamental trees, fruit trees, yards, hedgerows, or along roadsides.

Feeding Impacts

The fall webworm is an insect that usually does not create a problem within its native range (Drooz, 1985; Hill et al., 1982; Johnson and H.H., 1991; Sourakov and Paris, 2011). The fall webworm feeds on foliage in the mid to late summer after most trees have had time to photosynthesize, so few energy reserves or nutrients are lost (McCullough and Siegert, 1999). The webworm has unappealing aesthetic values, especially in parks and tourism spots where it can be seen by many people. Persistent outbreaks do occur and can encompass several kilometers causing branch and top-kill (Drooz, 1985), and losses in growth and seed production (Oliver, 1964).

Control

There are many different approaches to control fall webworm outbreaks but most are labor intensive and directed toward urban and individual high valued trees. These control tactics include: (1) mechanized control, which can be used to prune or destroy webs in small to medium sized trees, 2) chemical control using systemic insecticides or standard insecticide sprays, which

cause the webworm to be affected as it touches or walks over the spray, or ingests treated foliage; and 3) biological pesticides, such as the bacterial insecticide Bt (*Bacillus thuringiensis* var. *kurstaki*), which must be consumed to be effective and can be applied when the fall webworm larvae are small (McCullough and Siegert, 1999; Shetlar, 2000). In most situations populations are usually held below economic impact levels by native biological agents such as birds, small mammals, spiders, predaceous and parasitic insects, viruses (Morris, 1972; Oliver, 1964), and weather conditions. The fall webworm is attacked naturally by about 80 or more different predators and parasitic species, including one important egg parasite and two important caterpillar parasites (Johnson and H.H., 1991; Shetlar, 2000). Usually fall webworm outbreaks in general forest areas are not severe enough or last long enough that control efforts need to be considered.

Discussion and Recommendations

Native insects such as the fall webworm occur throughout the region served by the Northeastern Area State and Private Forestry. The level of activity for these insects fluctuates based on several factors—the availability of host material, the condition of the stand, changes in environmental conditions, and populations of predators and parasites. The fall webworm is normally not considered a major forest pest for a few reasons. The defoliation occurs in late season, the probability of outbreaks lasting longer than 1 to 2 years is low, and the number of predators and parasites attacking this pest is high. However, trees experiencing high defoliation will likely have reduced growth and branch dieback.

One of the purposes of this evaluation was to determine the current location and extent of fall webworm defoliation on the ANF. Historically, this would have been done by aerial surveys, which would have been used to detect and delineate outbreaks. Putting together an aerial survey over Federal land is a complex, costly, and risky endeavor. For this evaluation, we chose to use the available 240 by 240 m^2 MODIS data to determine the extent of the fall webworm outbreak across the ANF.

Since this was only a pilot study, only a small number of field sites were visited to assess the accuracy and precision of the MODIS data. Although the agreement between field surveys and the randomly selected single-pixel MODIS data was only in the 40 percent range for undetectable and detectable change in leaf condition, and only in the 30 percent range when looking at different levels of change, the information obtained by the two MODIS systems was useful. Although this project occurred over one season and with one pest, the results suggest good agreement between field surveys and MODIS data when change is severe. Significant amounts of error are likely associated when comparing MODIS change values to estimated defoliation values. Projects like this help to better interpret and define the precision and usefulness of this technology.

In discussions with both the FHTET and EFETAC groups, areas of ~20 contiguous pixels (280 acres) were suggested as the basic unit of change that would require a follow-up field visit (William Hartlove, personal communication, April 4, 2012), which roughly equals the ~300 acre average polygon size mapped during aerial survey flights in the Northeast (James Steinman, personal communication, May 31, 2012). With any remote sensing project, it is critically important to evaluate the accuracy of data being produced. In this project we assessed the accuracy of two different MODIS-derived datasets. Both MODIS datasets served their purpose by giving locations and a measure of the amount of change occurring within each pixel. They also helped define "hotspot" areas that had concentrations of pixels with detectable change, thus allowing a rapid assessment of the ANF and definition of areas where follow-up ground surveys should be conducted.

It is hoped that as MODIS and other remote sensing data become available and widely used, accuracy assessments like this will become a standard practice that helps better define the limitations and advantages of this technology.

Although fall webworm damage is rarely severe, keeping trees healthy is always important. Maintaining proper stocking levels and reducing stand susceptibility by diversifying species composition can all be used to reduce the impact of insect and disease agents on ANF lands.

Fall webworm control measures are not currently needed in general forest areas of the Allegheny National Forest. We recommend that the Forest incorporate annual insect and disease monitoring into its management plans for high-value areas such as campground or parks and, if needed, apply both long- and short-term insect and disease treatment strategies to minimize impacts and meet resource objectives.

Acknowledgements

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